IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appl. No.	:	10/676,277	Confirmation No. 6561
Applicant	:	Ferman	
Filed	:	September 30, 2003	
TC/A.U.	:	2624	
Examiner	:	Ge, Yuzhen.	
Docket No.	:	KAR:7146.0164	
Customer No.	:	55648	

DECLARATION OF PRIOR INVENTION IN THE UNITED STATES TO OVERCOME CITED PATENT OR PUBLICATION (37 C.F.R. § 131)

Chernoff, Vilhauer, McClung & Stenzel
601 S.W. Second Avenue, Suite 1600
Portland, OR 97204

January 23, 2008

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PURPOSE OF DECLARATION

1. This declaration is to establish reduction to practice of the claimed invention of this application in the United States at a date prior to February 19, 2003, which is the effective date of the primary reference Jarman et al, U.S. Patent Pub. No. 2004/0184670 cited by the Examiner.

2. The person making this declaration is the inventor, A. Mufit Ferman.

FACTS AND DOCUMENTARY EVIDENCE

3. A working prototype of the inventions claimed in the captioned application was constructed on a date prior to February 19, 2003. Attached to this declaration is an Exhibit showing an invention disclosure form, signed by me on a date also prior to February 19 2003, documenting the existence of a working prototype.

4. The date by which the prototype described in paragraph 3 was constructed is prior the effective date of the cited primary reference, Jarman.

5. This declaration is submitted concurrently with the filing of an RCE.

DECLARATION

6. As a person signing below, I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

SIGNATURE

M. Ferman 1/23/08

A. Mufit Ferman Date

SHARP Laboratories of America, Inc.
5750 NW Pacific Rim Boulevard
Camas, Washington 98607

SLA Confidential

SLA Docket No. SLA1346

INVENTION DISCLOSURE FORM

Revised 4/02

Has a provisional patent application or related patent application been filed previously for this case or a closely related case? If so, indicate SLA numbers of previously filed cases.

SLA____	Relation: (i.e., provisional, continuation-in-part, or just technically related)
SLA____	Relation:
SLA____	Relation:
SLA____	Relation:

2. Descriptive Title of Invention:

Method and System for Automatic Detection of Red-Eye Artifacts in Digital Color Photos

3. Inventor(s):

Full Legal Name:	Ahmet (First)	Mufit (Middle)	Ferman (Last)		
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Citizenship:					
Telephone:	(Home)	(Company)			

M. Ferman Inventor Signature	[redacted] Date		
Inventor Signature	Date	Witnessed & Understood By	[redacted] Date
Inventor Signature	Date	Witnessed & Understood By	[redacted] Date

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SLA Docket No. ____________

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Address:	Street	City	State	Zip	County
Citizenship:					
Telephone:	Home	Company			

Supervisor's Acknowledgment: "I believe this disclosure is novel and complete and should be submitted to the Patent Review Committee."

Supervisor's Signature: Michael A. Kriss
Date: [redacted]

Supporting Group: ☐ CRDG ☐ AVSG ☐ CSG ☐ ISG ☒ DSG ☐ ICG ☐ LCDG ☐ Other: ____________

Inventors' Department: ☐ DV ☐ MMC ☒ DI ☐ IST ☐ IC ☐ LCD

4. **Project & Supervisor:**

Supervisor's Name: Michael A. Kriss

Supervisor's Title: Manager, Color & Imaging Group

Project Number/Name: IUIP06 – Object Identification & ROI

5. **Conception of the Invention:**

Date Conceived: Approx. [redacted]

Date of first Written Description: [redacted]

Notebook & Page No. or File Archive: ____________

Date first explained to others (whom?): [redacted]

Planned Application for the Invention: Printer, copier, scanner and digital camera image pipelines; document/image management and manipulation software

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Inventor Signature	Date	Witnessed & Understood By	Date: [redacted]
Inventor Signature	Date	Witnessed & Understood By	Date: [redacted]

6. **Construction & Test of First Prototype Embodying the Invention**

Date First Prototype Completed: [redacted]

Part Number/Product Description: ______

Date of First Successful Test: ______

Successful Operation Witnessed By: ______

7. **Public Disclosure of Invention (Presentation at public meeting or publication (NOTE: Patent Application MUST be filed prior to any public disclosure.).**

Date of First Public Disclosure: None

Setting (Conference/Journal Name): ______

Title of Paper or Presentation: ______

Type of Disclosure (Written/Verbal): ______

Does Data Sheet or Application Note Disclose the Invention (when)? ______

8. **Would one skilled in the art of your invention need to refer to any published documents, in addition to your disclosure, in order to make and use your invention? If so, list references and summarize background material therein.**

No additional references are required for a person skilled in the art of this invention to understand, make, and use the proposed method.

9. **Briefly summarize the primary unique aspects of your invention and the problems solved by the invention.**

Red-eye is a common phenomenon that occurs during flash photography. In an environment where a flash is needed to illuminate the subject, the subject's pupils are dilated due to the low ambient illumination. Light from the flash can then enter the eye through the pupil and be reflected off the blood vessels at the back of the retina. This reflection is recorded by the camera if the geometry of the camera lens, the flash, and the subject's eye is just right, rendering the captured image unpleasant and objectionable to viewers. Hence there is a significant need for automatic methods that identify and correct red-eye areas in a captured image.

A number of methods have been proposed in the prior art for detecting and/or removing red-eye artifacts. Most of these methods are either (i) supervised; i.e. they require the user to manually identify the subregions in an image where the artifacts are observed, or (ii) dependent on skin/face and/or eye detection to find the areas of interest. In this invention we propose an unsupervised red-eye detection technique that uses low-level image features to locate the red-eye pixels in a digital image. The algorithm does not require detection of the face and/or skin regions in an image, and is therefore significantly different from the prior art. Another advantage of the invention is that it limits

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
Inventor Signature	Date	Witnessed & Understood By	Date

processing to those areas in the image that are affected by the flash illumination, since the red-eye phenomenon is a direct result of flash use. The computational overhead is therefore reduced considerably. The algorithm utilizes low-level image features and basic processing techniques such as median filtering and morphological operations, as well as color- and shape-based constraints, repeatedly and in succession to reduce the number of candidate regions that may correspond to red-eye. Furthermore, each component of the image color space is analyzed in a specific way, and the results are finally merged to yield a more reliable output. The invention can be implemented as a stand-alone computer application that operates on digital images or as a plug-in to other image/document management software (e.g., SharpDesk, Photoshop); or it may be incorporated into an MFP.

10. Detailed Description.

Fig. 1 illustrates an embodiment of the invention. The input to the system is a color digital image, which may be in any one of a number of difference color spaces. In the current embodiment, the input image is converted into the HSV (hue/saturation/value) or HSI (hue/saturation/intensity) color space, where the rest of the processing occurs. Specifically, each channel of the HSV color space is processed and analyzed in various ways to accurately identify the red-eye artifacts.

As discussed in the previous section, red-eye artifacts occur as a direct consequence of flash. The red-eye detection method therefore focuses only on those regions of the image that have been affected (i.e. illuminated) by a flash. To identify these regions a thresholding operation is first applied to the brightness (V) component I_v of the image. The pixels that exceed the threshold value T_f comprise the flash mask, M_f:

The value of threshold T_f can be selected in various ways. In the current embodiment, T_f is computed for each input image individually using Otsu's thresholding method (Otsu, N. (1979), *A thresholding selection method from gray-level histogram*, in *IEEE Trans. Syst. Man Cybernet.* 9(1), 62-66.); however, other threshold selection methods can also be used. Furthermore, the value of T_f can be used to determine whether the input image is a flash image or not.

Once the initial flash mask is obtained, several post-processing operations can be applied to refine it by eliminating isolated pixels. These operations may include, but are not limited to, median filtering, morphological operations such as erosion and opening, and so on. The remaining pixels in M_f are then grouped into contiguous regions using a connected component labeling algorithm, and the areas of the labeled regions are computed. Regions with areas smaller than a predetermined threshold are discarded. The convex hull of each remaining region is subsequently computed and a binary mask that comprises the union of the convex hulls is constructed to yield the final flash mask M_f. Figure 2 highlights the various stages in the construction of M_f. Fig. 2(a) depicts the input image I; the V component of the image, I_v, is shown in 2(b). The results of the thresholding and post-processing operations are shown in Figs. 2(c) and (d), respectively. The final flash mask M_f, obtained after area-based thresholding and convex hull generation, is depicted in 2(e). M_f represents the areas in the input image that may contain red-eye artifacts; therefore, the rest of the processing is restricted to the regions identified by M_f.

After M_f is computed, it is used to perform further processing on the hue component I_h. We first apply M_f to I_h and obtain a masked version I_h^m. Hue corresponds to the dominant color of a pixel, and it is

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
Inventor Signature	Date	Witnessed & Understood By	Date

represented as an angle on the unit circle between 0° and 360°. When the hue values are mapped to an appropriate interval for display (e.g., to [0,1] or [0,255]), red-eye locations are observed to always appear as light, contiguous regions on darker backgrounds, as shown in Fig. 3(a). We exploit this property by thresholding I_h^m to eliminate the dark areas and thus reduce the area that needs to be analyzed for red-eye artifacts:

The value of the threshold T_h can be chosen in different ways. In the current embodiment, $T_h \in [0,1]$, and is set to 0.125.

After M_h is obtained, several post-processing operations may be applied to refine it. These operations may include, but are not limited to, median filtering, morphological filtering such as dilation and closing, and so on. The selected pixels in M_h are then grouped into contiguous regions using a connected component labeling algorithm, and several features are computed for each labeled region. Specifically, we consider the area, aspect ratio, and extent of every region to determine the likelihood that the region is a red-eye area. *Extent* is defined as the ratio of the total area of the region (i.e. the number of pixels in the region) to the number of pixels in the smallest bounding box for the region. Regions whose areas and/or aspect ratios fall outside predetermined ranges, or whose extent values are below a specified threshold, are discarded. In the current embodiment, the minimum and maximum allowed sizes for a region are computed dynamically based on the size of the input image. The aspect ratio test allows us to eliminate regions that are elongated; the aspect ratio of a candidate red-eye region is expected to be in the interval (0.33,2). Finally, if the extent of a region is less than 0.33, the region is removed from the list of candidate red-eye locations.

Figure 3 highlights the various stages in the construction of M_h. Fig. 3(a) depicts the hue component I_h of the image; the masked hue component, I_h^m, is depicted in 3(b). The result of the thresholding and post-processing operations is shown in Fig. 3(c). The final hue mask M_h, obtained after connected component labeling and area- and shape-based filtering is depicted in 3(d).

Next, we utilize the information in the saturation component of the image to further refine the list of candidate red-eye regions. It is observed that pixels in the red-eye regions often have high saturation values, as seen in the example image in Fig. 2(a). This phenomenon is also clearly demonstrated in Fig. 4(a), which shows the saturation component I_s for the example image. Furthermore, the local variation in the saturation component is highly pronounced around the red-eye regions. To exploit this property we then compute the standard deviation of the saturation component for each pixel using a local neighborhood (Fig. 4(b)). Pixels that are likely to be red-eye artifacts are then identified by a thresholding operation, which yields the saturation mask M_σ, as shown in Fig. 4(c). The value of the threshold can be chosen in different ways. In the current embodiment, it is set to 0.15 based on empirical evidence.

The intersection of M_h and M_σ is then computed to yield a final mask $M_{h\sigma}$ (Fig. 4(d)) that represents the locations where the red-eye artifacts are most likely to occur. As in earlier stages of the algorithm, several post-processing operations may be applied to refine $M_{h\sigma}$. These operations may include, but are not limited to, median filtering, morphological filtering such as dilation and closing, and so on. The selected pixels in $M_{h\sigma}$ are then grouped into contiguous regions using a connected component labeling algorithm, and several shape-based features are computed for each labeled region. Specifically, we compute the

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
Inventor Signature	Date	Witnessed & Understood By	Date

eccentricity and circularity of every region. *Eccentricity* is defined as the ratio of the distance between the foci of the ellipse that has the same second-moments as the region and its major axis length. The value of eccentricity varies between 0 and 1; the higher the eccentricity value, the closer to a line segment the region is. *Circularity*, as the name implies, is a measure of how closely a region resembles a circle, and is defined as the ratio of the square of the region perimeter to the area of the region. These properties are used to determine the likelihood that a particular region contains red-eye artifacts (Fig. 4(e)). The final stage of the algorithm involves color-based analysis of the remaining regions to determine which pixels are strongly red. This can be achieved using the hue component, by specifying the appropriate range of hue angles corresponding to color red. Alternatively this color test can be carried out in other color spaces, such as RGB, YCrCb, La*b*, and so on. In the current embodiment, we utilize the RGB values of the pixels in each candidate region to determine whether the region contains a red-eye artifact. The RGB values can be computed directly from the available HSV components be means of a simple transformation. For every region, we compute the mean of each primary. We then observe whether (i) the mean red value is less than a specified threshold, or (ii) the ratio of the means of the green and blue components is below another predetermined threshold. Any region that satisfies either of the above criteria is discarded, and the remaining regions are declared red-eye artifact locations (Fig. 4(f)). The individual pixels that require correction within these regions are identified through an analysis of the color properties of the individual pixels. This analysis may include, but is not limited to, thresholding based on pixel color values, clustering/region growing based on color similarity, and so on. The final output of the algorithm is a mask that identifies the individual pixels in the image that require red-eye correction.

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
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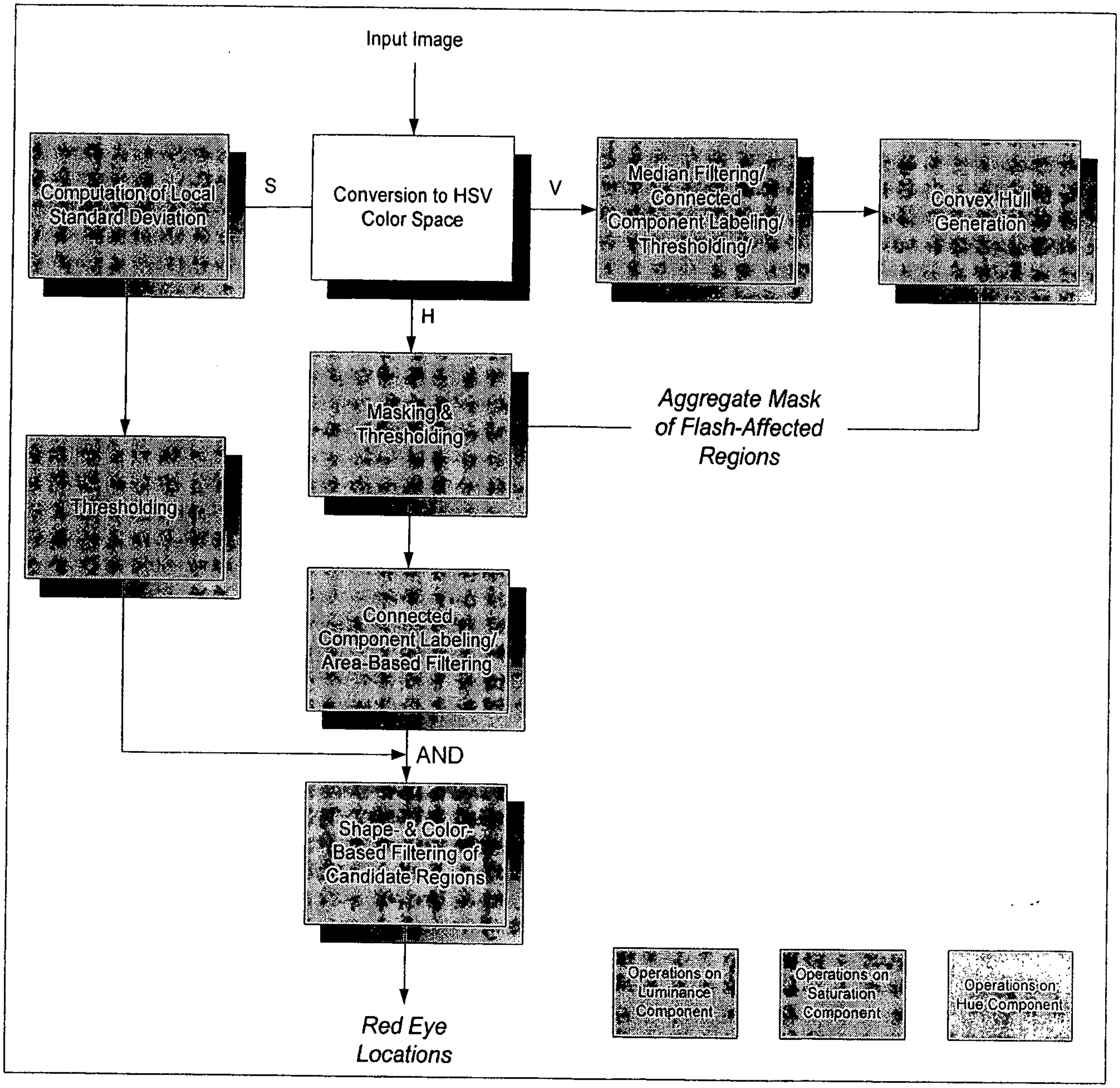

Figure 1 Flowchart of the automatic red-eye detection system

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
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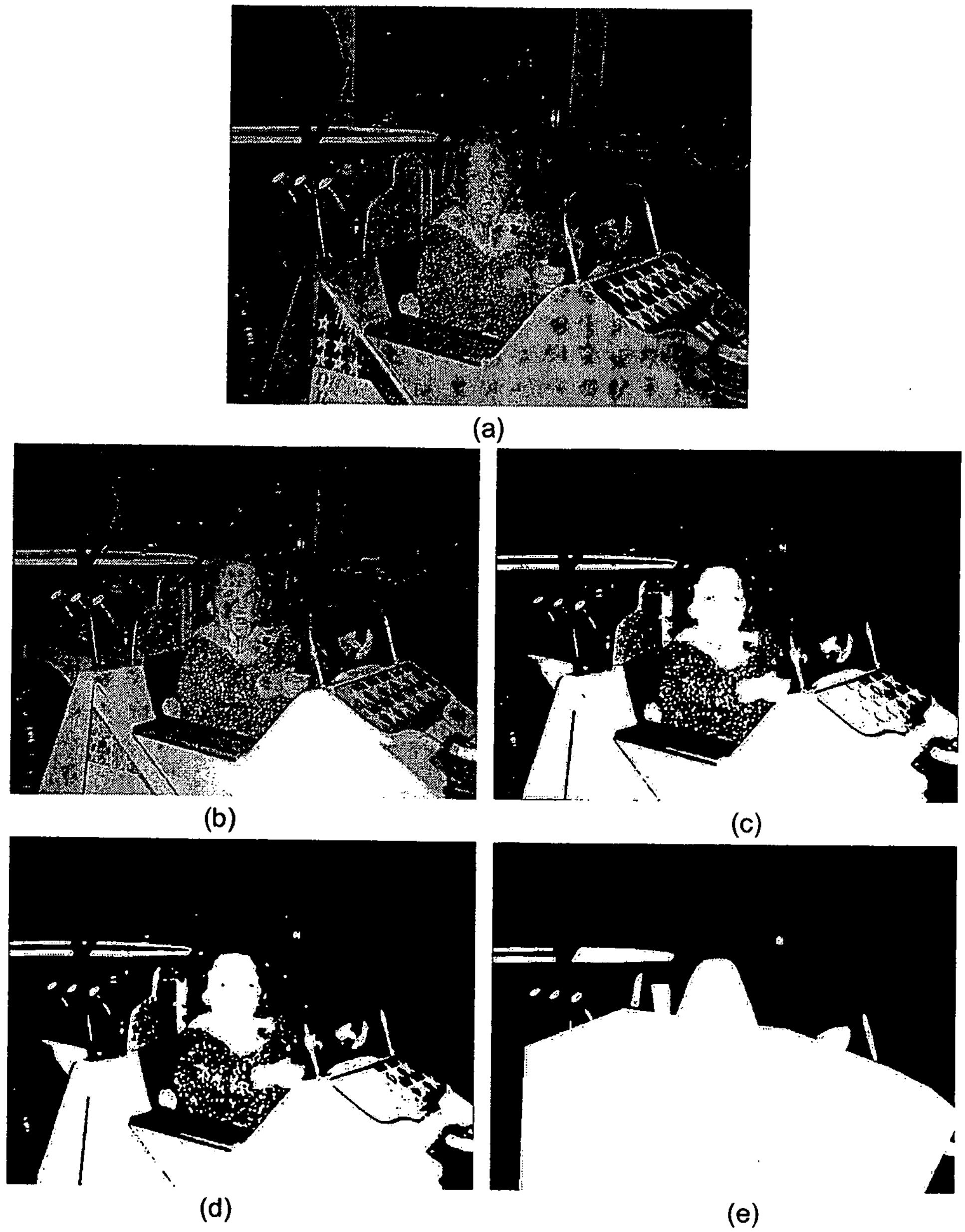

Figure 2 Construction of the flash mask for the input image using the brightness component: (a) Original input image; (b) brightness component I_v; (c) flash mask If obtained after thresholding by T_h; (d) I_f after post-processing to eliminate isolated pixels, and (e) final mask image M_f, obtained after connected component labeling, area-based thresholding and convex hull generation.

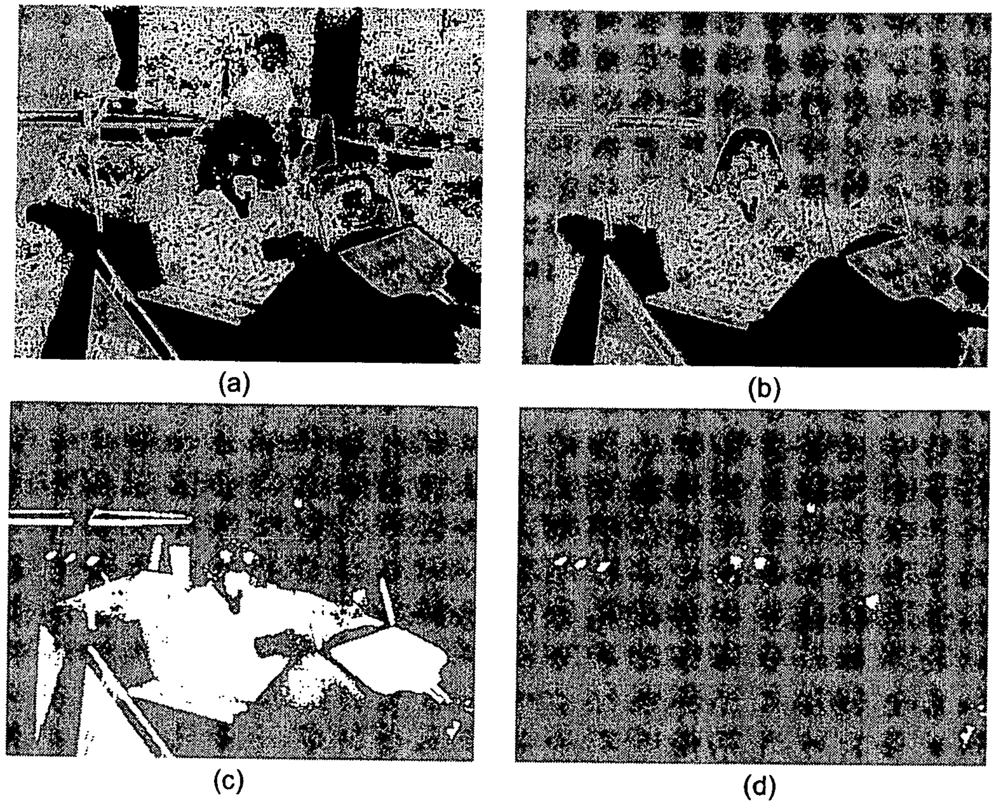

Figure 3 Identification of candidate red-eye regions using M_f and the hue component: (a) Hue component I_h; (b) I_h^m obtained after masking I_h by M_f; (c) remaining regions in I_h^m after thresholding and post-processing operations; and (d) final set of candidate red-eye artifact locations after connected component labeling and area- and shape-based filtering. (The unprocessed background regions are shown in blue.)

Inventor Signature	Date		
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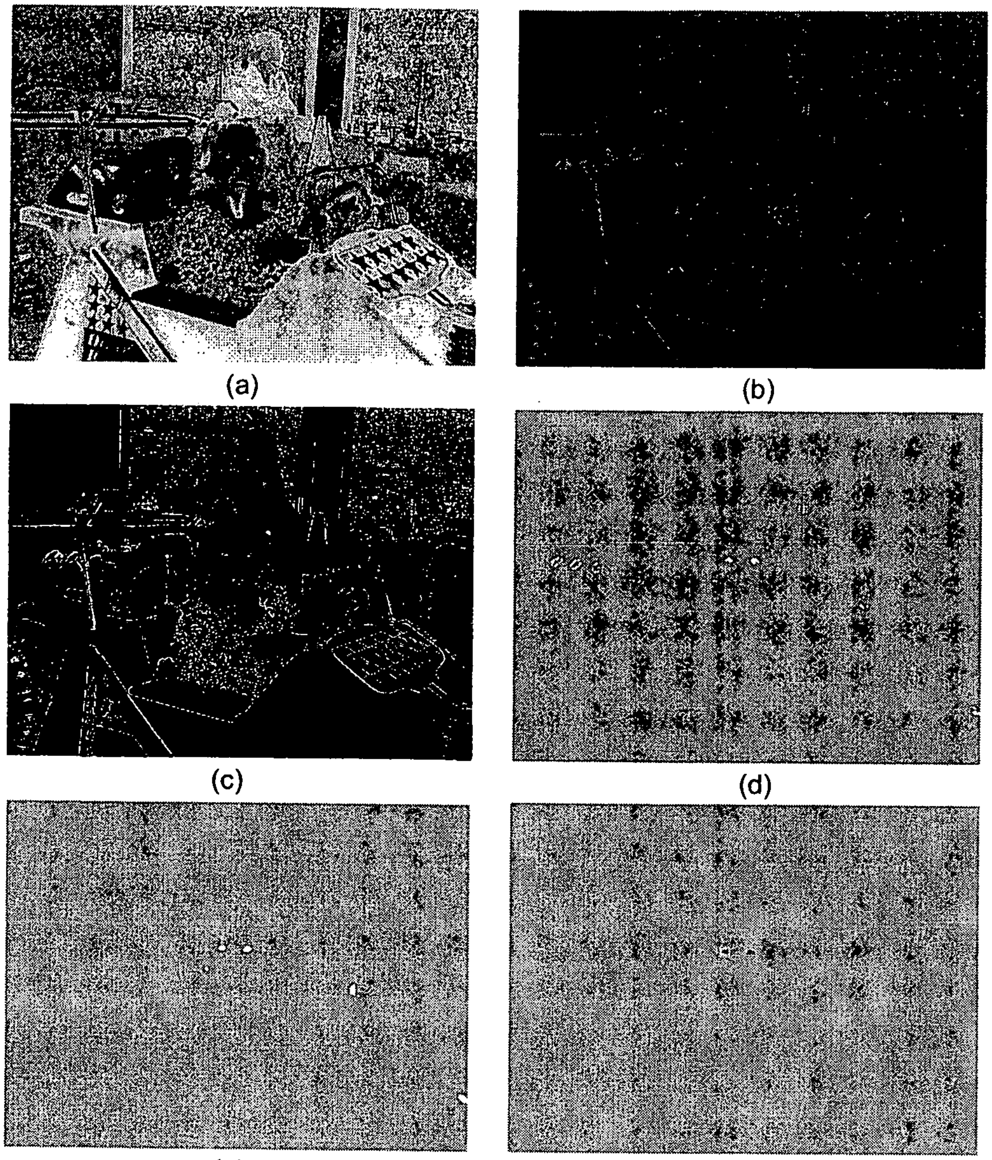

(a) (b) (c) (d) (e) (f)

Figure 4 Identification of the red-eye artifact regions using the saturation component: (a) Saturation component I_s; (b) standard deviation map $I_{s\sigma}$; (c) mask obtained by thresholding $I_{s\sigma}$; (d) candidate red-eye regions obtained by intersection of M_h and M_σ, and after (e) shape-based filtering, and (f) final red-eye locations identified after color-based analysis. The pixels in these regions are further inspected individually to determine those that require correction. (The unprocessed background regions are shown in blue.)

Inventor Signature	Date		
Inventor Signature	Date	Witnessed & Understood By	Date
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